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Organic substitution in fertilizer schedule: Impacts on soil health, photosynthetic efficiency, yield and assimilation in wheat grown in alluvial soil

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ABSTRACT

Management of soil in agricultural ecosystem is considered to be important in maintaining soil health and soil carbon storage. Various combinations of inorganic fertilizers, FYM and crop residues were assessed in a wheat crop grown in alluvial soil for two consecutive years. We studied several attributes like soil organic carbon (SOC), soil total carbon (TC), soil carbon storage (SCS), soil moisture content (SMC), easily mineralizable N along with above ground and below ground biomass, photosynthetic rate and grain yields during various growth stages. Wheat biomass yield was increased with application of organic amendments, while carbon assimilation by plant photosynthesis during the reproductive stages enhanced with increment of SOC. We recorded about ~10.88% and 10.52% organic SCS in soil depth of 0–15 cm and about ~11.50% and 12.46% in soil depth of 15–30 cm under 100% NPK + CR + FYM and 80% NPK + CR + FYM treatments, respectively. Hence, CR and FYM in combination can maintain SOC stock considerably and 80% NPK + CR + FYM substitutes 20% inorganic fertilizer without compromising crop growth and development.

1. Introduction

Annual green house gas emissions from agricultural production in 2000–2010 were estimated at 5.0–5.8 GtCO_2 eq year^{-1}; therefore, leveraging the mitigation potential is extremely important in meeting emission reduction targets (IPCC, 2014). Soil is considered as the primary reservoir of organic carbon (C) in terrestrial ecosystems (Larionova et al., 2008). The amount of carbon in terrestrial ecosystem is about 3170 Gt and nearly 80% (2500 Gt) of this amount is found in soil (Lal 2007). Soil organic carbon (SOC) depletion is potentially related with yield decline of rice and wheat crops (Ladha et al., 2003; Pathak et al., 2003). However, carbon sequestration potential can be changed by many factors such as climate and soil conditions (Miller et al., 2004; Chabbi et al., 2009), cropping systems (Jagadamma and Lal 2010), managements including tillage (Ogle et al., 2005) and balanced fertilization (Bhattacharyya et al., 2007).

Crop residues containing 45% of C on dry weight basis are the main source of C in agricultural soils (Jarecki and Lal, 2003). However, the amount of crop residues returned to the soil depends on nature of crop, soil factor and crop management. Whereas, use of farm yard manure or green manure along with incorporation of crop residues effectively enhance soil carbon storage (Singh et al., 2007; Brar et al., 2013).

The global soil respiration (SR) flux is 75×10^{15} gC year^{-1} (Schlesinger and Andrews, 2000), accounting for about 80% of the gross ecosystem respiration (Longdoz et al., 2000). Therefore, a small change in the soil respiration rate may dramatically alter atmospheric CO_2 concentrations and soil C sequestration (Iqbal et al., 2009). Generally, soil CO_2 emission includes root respiration and heterotrophic (microbial respiration using original soil organic carbon) respiration (Savage et al., 2009). The knowledge about the quantum of CO_2 released from the soils helps to understand the changes in soil to atmosphere CO_2 fluxes (Raich and Mora, 2005). However, soil respiration in agro-ecosystem greatly varies according to crop management practices (Zhang et al., 2013). Application of organic amendments in soil leads to increment of CO_2 emission by providing mere substrates to the microbes (Bhatia et al., 2005; Li et al., 2008). Consequently, we are emphasizing on reduction of CO_2 emission with the application of FYM and CR without sacrificing grain productivity. Under these perspectives,

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Table 1
Basic soil properties of the experimental field at (0–15) cm and (15–30) cm depth (mean ± standard deviation).

Soil properties	(0–15) cm	(15–30) cm
SOC (%)	1.29 ± 0.08	0.90 ± 0.03
TC (mg g^{-1})	14.09 ± 1.06	11.45 ± 0.32
pH	5.19 ± 0.06	5.40 ± 0.32
SM (%)	22.18 ± 3.15	25.72 ± 3.76
Available N (kg ha^{-1})	152.63 ± 11.9	130.80 ± 23.03
Available phosphorus (kg ha^{-1})	36.66 ± 3.26	29.75 ± 1.03
Available potassium (kg ha^{-1})	235.72 ± 67.1	140.52 ± 35.36
Bulk density (Mg m^{-3})	1.25 ± 0.02	1.37 ± 0.02
Sand (%)	60.19 ± 0.94	–
Silt (%)	21.10 ± 0.94	–
Clay (%)	18.80 ± 2.31	–

we conducted a two year field experiment in an intensively cultivated alluvial soil. Different levels of inorganic fertilizers were applied with varying proportions of crop residues (CR) and farm yard manure (FYM) to wheat crop. The major objective of this study was to evaluate the effects of integrated nutrient management schemes on soil C stock and crop improvement. Moreover, we were interested in recognizing overall impact of substitution of chemical fertilizers with organic amendments in regard to soil quality and productivity.

2. Materials and methods

2.1. Experimental site

A field experiment was conducted at North Bank Plain Agroclimatic Zone of Assam at Tezpur University campus (26°41′N and 92°50′E) Assam, India for two consecutive seasons in 2011–2012 and 2012–2013. The region is subtropical humid and is characterized by moderately hot wet summers and dry winters. The soil of the experimental field is characterized as sandy loam to silt loam texture, which is rich in organic matter. Soil samples were collected from the experimental field before the start of each experiment for the analyses of physical and chemical properties (Table 1). Precipitation and daily temperature levels were recorded during the experimental period from December to April for 2011–2012 and 2012–2013 starting from the date of sowing to eight days after the harvest (Fig. 1A and B). The total rainfall

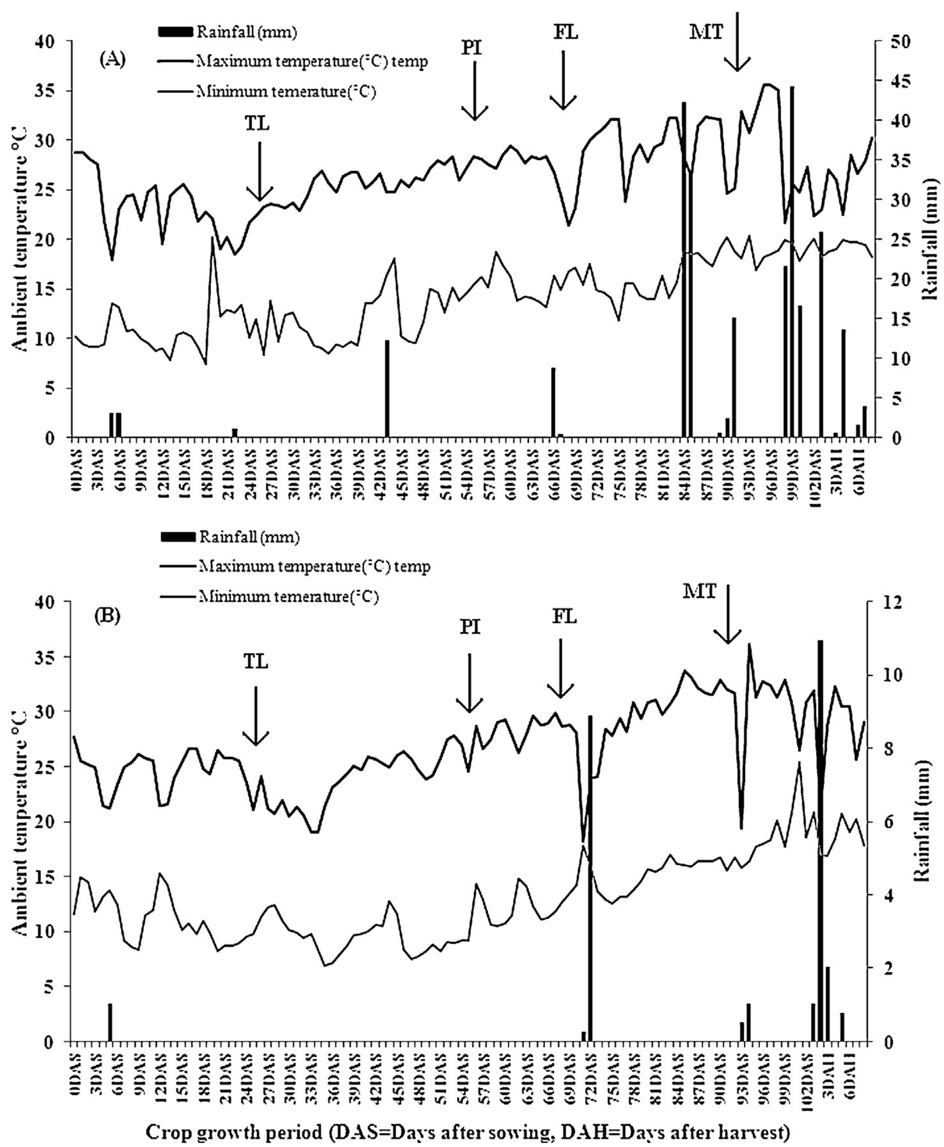

Fig. 1. Daily rainfall and maximum and minimum air temperature during the crop growth period: (A) first year (2011–2012), (B) second year (2012–2013) from December to April. TL = tillering, PI = panicle initiation, FL = flowering and MT = maturation stages during wheat cultivation.